Program Progress Report
CDRL A002

Pilot-in-the-loop Method Development

2012 Basic and Applied Research in Sea-Based Aviation

ONR #BAA12-SN-0028

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1 PROJECT OVERVIEW

The goal of this project is to integrate novel numerical modeling and computer hardware approaches to compute the non-linear aerodynamic coupling between the ship and aircraft in such a way that execution times are at real-time speeds, allowing for pilot-in-the-loop CFD to be integrated in the piloted flight simulation environment. To achieve the speed gains required, three areas will be targeted for implementation into the CFD simulation framework: (1) numerical algorithms, (2) novel domain boundaries, and (3) Graphical Processing Unit (GPU) hardware. A framework will be established to link the CFD with realtime simulations. A building block approach will be employed to first demonstrate non-realtime integration of the CFD simulation framework with helicopter flight dynamic models, then realtime execution for a minimum fidelity airwake/aircraft simulation, then build to higher fidelity realtime simulations.

1.1 Project Technical Objectives

The project involves the following seven tasks to accomplish the technical objectives of the project:

Task 1: Implement modular implicit/explicit solver

Task 2: Apply structured numerics

Task 3: Apply subdomain with immersed boundary

Task 4: Implement higher order explicit solver for GPU execution

Task 5: Integrate with the GENHEL-PSU flight dynamics model

Task 6: Demonstrate flight simulation in the PSU Rotorcraft Simulation Facility

Task 7: Demonstrate flight Simulation in NAVAIR Manned Flight Simulator

2 WORK SUMMARY

During this reporting period, a review meeting was held at Patuxent River NAS to review the task schedule and discuss collaboration with Penn State University. Near term goals were defined:

1. Focus structured calculations on the LHD as the target ship platform
2. Target smaller structured grids than the initial LHA calculations (on the order of 10 million cells)
3. Evaluate structured results against standard practices (unstructured grids on the order of 30 million cells) using time averaged and PSDs of velocity components at spot locations on the ship. The goal will be to obtain results from the structured calculations within 10%.
4. Evaluate methods for speeding up structured solver
5. Work with Penn State University to get GENHEL model integrated with the solver – initially this will be for the CRUNCH CFD unstructured solver. Begin with 1-way coupled simulation, then progress to fully coupled simulations.
6. Collaborate with NAVAIR and PSU to develop communication protocols that are similar to the CASTLE/Kestrel coupling approach.

Additional numerical studies were performed using the LHA structured airwake case, shown in Figure 1, as well as other cases to investigate the runtime performance impact of using GPU-enabled clusters as the target computational platform for ship air-wake modeling simulations. Based on an internal research study, it was learned that runtime acceleration factors approaching 80 could be achieved using an NVIDIA K-20 graphics card in comparison to a single Intel Sandy Bridge CPU. This runtime acceleration benefit was based on LES benchmarking studies for jet aero-acoustic prediction applications and utilized 5th-order spatial numerics as well as explicit Runge-Kutta time-stepping advancement. The challenge presented was to enable the wake calculation to be run in real-time; for target performance purposes, this has implied the ability to run with a computational advancement time-step of 0.01 seconds (or higher) within a physical computational runtime cost of 0.01 seconds (or less). For the LHA ship model case, practical time-steps of only 1e-06 time steps were achievable within the

explicit Runge-Kutta framework. This result has prompted the need to port fully implicit numerics onto the GPU.

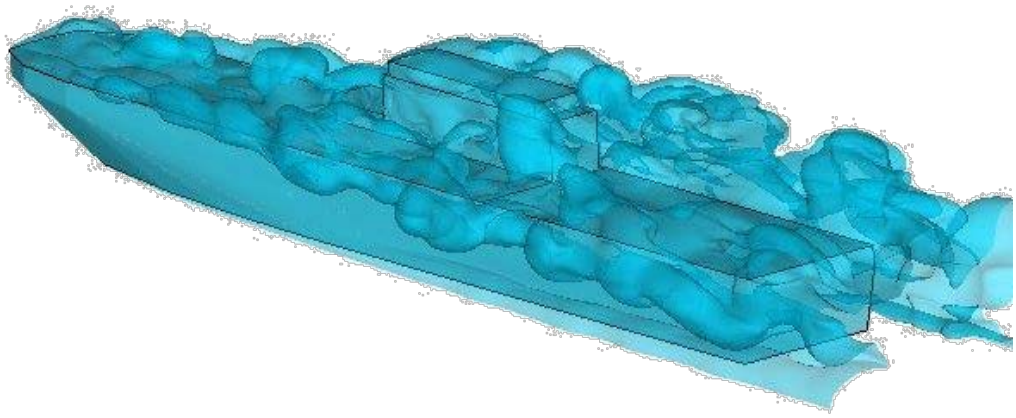

Figure 1: Structured LHA Airwake Simulation using CRAFT CFD.

3 TECHNICAL/COST STATUS AND PROBLEM AREAS

No technical or financial problems have been encountered.

4 MEETING AND/OR TRAVEL

A review meeting was held at Patuxent River NAS on February 27, 2014.

5 CONTRACT SCHEDULE

The program is proceeding as planned.

6 PLANNED ACTIVITIES FOR NEXT REPORTING PERIOD

Future activities will involve performing structured calculations of an LHD ship platform for more rigorous performance comparisons between the structured and unstructured approaches in accordance with the near term goals discussed at the review meeting. Additionally, so that PSU researchers may begin developing interfaces between the CFD airwake and GENHEL model, CRAFT Tech will be installing CRUNCH CFD on PSU computing clusters and assisting with airwake computations.

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